Using Distribution Uniformity to Evaluate the Quality of a Sprinkler System

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Introduction:

As demand upon urban water resources continues to increase, more attention has been focused upon landscape irrigation. The expectation is that automatic sprinkler systems will save water, but the reality seems that they use even more water. The possibility to save water exists if the sprinkler system is well managed, but overall irrigation efficiency cannot be better than the sprinkler system. The Irrigation Association offers the Certified Landscape Irrigation Auditor program that includes taking the auditor training class and passing an exam. As part of this class, students learn a standardized method to evaluate how well a system performs including how much water is applied in a given time frame as well as how evenly the water is applied. By using catch cans to perform an irrigation audit, the data collected can provide an indication on the quality of the sprinkler system that reflects the quality of the components, design, installation and long-term maintenance of the system. The lower quarter distribution uniformity is often used as the basis to judge the quality of the system. Current IA Turf and Landscape Irrigation Best Management Practices (February 2004) state that fixed spray heads should have a minimum lower quarter distribution uniformity of 55% and rotors should have a minimum DU of 70%.

This paper presents the findings from landscape irrigation audits done in various parts of the United States when evaluating the quality of the sprinkler systems using catch can data and calculating lower quarter Distribution Uniformity (DU).

Background Information:

In the Turf & Landscape BMPs as well as several training manuals from the Irrigation Association such as Landscape Irrigation Auditor, Sprinkler System Scheduling and Predicting and Estimating Landscape Water Use to name a few, the following table is provided describing the quality of the sprinkler system based upon the type of sprinkler heads based on lower quarter distribution uniformity.

Rating of Lower Quarter Distribution Uniformity (DULQ) for Sprinkler Zones

Type of Zone	Excellent (%)	Very Good (%)	Good (%)	Fair (%)	Poor (%)
Fixed Spray	75	65	55	50	40
Rotor	80	70	65	60	50
Impact	80	70	65	60	50

One item that jumps out to users of the BMPs is that minimal acceptable performance for spray heads of 55% falls in the “Good” category while rotor and impacts heads are in the “Very Good” category with 70% as the acceptable minimal performance. This has caused some confusion among end users and perhaps needs better explanation as to why the minimal expectation is not the same for different types of heads. This standard is not unique to the Irrigation Association only but has been implemented by various water purveyors or governmental agencies. Some agencies have used 60% as the minimal DULQ for fixed spray heads that is between good and very good according to the above table. In Australia the recommended minimum distribution uniformity based on lowest quartile is 75% and in the Georgia program for Landscape and Turf Irrigation Auditing a low quarter DU of 80% was deemed “adequate”.

In the August 2004 draft document “Landscape Irrigation Scheduling and Water Management from the Irrigation Association Water Management Committee, section Four provides a table discussing the quality rating of the overall irrigation system based on a weighted average of area as follows:

Quality Rating of the Overall Irrigation System

Quality of the Irrigation System	Irrigation System Rating (ISR)	Distribution Uniformity (DU_{LQ} overall)
Exceptional	10	> 85%
Excellent	9	75-84%
Very Good	8	70-74%
Good	7	60-69%
Fair	5	50-59%
Poor	3	40-49%
Fail	< 3	< 40%

Although this table is an idea presented by the Water Management Committee and needs further discussion it points out the need for most zones on a project to perform very well in order to compensate for those zones that fall at or below the minimal acceptable range. This table is for the overall irrigation system as a whole and not sprinkler individual zones. The quality of sprinkler system has an impact on the amount of water used to maintain a landscape. For example, in California Assembly Bill 325, the Water Conservation in Landscaping Act of 1990 requires that the Department of Water Resources develop a Model Water Efficient Landscape Ordinance. This Model Ordinance was adopted and went into effect January 1, 1993. In this ordinance irrigation efficiency for landscape irrigation systems must be a minimum of 62.5%. That would require that a site have a “Good” irrigation system and perfect water management in order to comply with the requirements. To compensate for the lack of perfect management, then a better quality sprinkler system such as “Very Good” or “Excellent” would be needed.

Turf Irrigation System Audits:

A few papers have been published discussing the results from audits, but most audit information is not formally published but is used to help educate the water manager or homeowner. But a sufficient number of audits have been conducted with similar results from the various locations in the United States that is makes for an interesting study to see how well turf irrigation systems are performing. Auditing techniques have been somewhat varied and adapted to local circumstances as well as needs of the auditing agency.

It is not the intent to discuss which auditing method or technique is the best or most correct but I will propose that there should be a minimum number of catch cans used to determine distribution uniformity. The size of area or the number of heads used to irrigate the area quite often dictates the number of catch cans used to perform the audit. The more catch cans used, the better or more reliable the measurement will be.

The method taught by the Irrigation Association and it is similarly taught by the Irrigation Training and Research Center at Cal Poly San Luis Obispo or the Landscape Irrigation Auditing and Management program offered by Texas A & M is to put a catch can near the head and then half-way between the head. Other areas used a grid pattern within the area being irrigated with a fixed spacing for the catch cans. Some auditing programs used two catch cans near the head and two in-between the sprinkler heads. Still other areas have used an abbreviated method to measure sprinkler system performance by using three or four catch cans strategically placed within the zone. While there are various ways the audits are being done, many programs have a minimum number of catch cans required for their method of conducting an irrigation system audit.

In Utah the guideline is 12-20 catch cans as a minimum. Colorado communities along the Front Range that are conducting audits for their customers have standardized informally on a minimum of 20 catch cans. Mobile Irrigation Laboratories (MIL) in Florida has a 16-24 catch can minimum requirement that is based upon how other mobile irrigation laboratories have operated in California and Texas. In Australia the minimum number of catch cans to be used is 20.

As can be seen there is not an absolute number of catch cans required, but those that have a minimum requirement see the need for a sufficient number of data points to calculate lower quarter distribution uniformity. Too few data points can lead to erroneous results. An item of observation is that most auditors choose to do the minimum when in reality more data points will provide a better measurement of sprinkler head performance. This becomes especially true when auditing large radius rotors. “Near a head and halfway between the heads” on large rotor systems leaves a lot of space between catch cans and the results could be eschewed. Moving the catch cans a few feet one way or another can dramatically change the results. In the Golf Irrigation Auditor Training by the IA the minimum recommended catch can spacing is to divide the space between the heads into thirds (use two catch cans between the heads) for auditing the fairways and on the tee boxes and greens a grid pattern is established placing the catch cans 10-15 feet apart depending on the size of area.

Although there are not any standards specifically for performing a landscape irrigation audit, some have adopted existing standards and modified them to fit the landscape situation. Some of these existing standards include:

ASAE S398.1 Dec 99 Procedure for Sprinkler Testing and Performance Reporting
ASAE S436.1 Dec 2001 Test Procedure for Determining the Uniformity of Water Distribution of Center Pivot and Lateral Move Irrigation Machines Equipped with Spray or Sprinkler Nozzles
ISO 7749/2 Irrigation Equipment Part 2, Uniformity Distribution & Test Methods

As already stated, these standards do not specifically address turf and landscape irrigation systems but they do provide guidelines that could be used for performing sprinkler system evaluations.

Sources of Audit Information:

The data used for this paper come from a variety of sources. For Utah three sources were used. Earl K. Jackson is the primary author for two reports documenting the results for the Slow the Flow, Save H2O campaign in Utah. The report "Saving Utah Water in the Fifth Year of Drought" focuses on residential properties after more than 4500 audits have been performed covering communities in six counties, while the other report "Irrigation Water Audits of Large Properties 1999 through 2003" summarizes the audit results on 166 commercial type properties. Another source of information was personal communication provided by Roger Kjelgren with Utah State University showing the audit results of 164 residences in the Logan, Utah area during the summer of 2004.

The data for Colorado was personal communication to the author from Laurie D'Audney, City of Fort Collins, Anne Haueter formally a summer intern with City of Loveland and now with Centennial Water & Sanitation District in Highlands Ranch, Colorado and Tiffany Graham working with communities in Boulder County. These audits were performed in 2003 and 2004.

Jill Hoyenga, Water Management Specialist with the Eugene Water & Electric Board provided data from the "quick & easy" audit versus a "full-blown IA" audit that she uses to teach homeowners about uniformity and irrigation scheduling. She uses only three catch cans and the calculated distribution uniformity would be best described as lower-third distribution uniformity. From past audits conducted by the author, the lower third distribution uniformity was usually 3-9 points higher than the lower quarter distribution uniformity. For purposes of comparing sprinkler uniformity in the various parts of the country, the lower-third distribution uniformity numbers she provided have been reduced by an average of 6 points to reflect a lower quarter distribution uniformity number.

In a paper presented at the 2003 ASAE Florida Section Meeting entitled “Residential Irrigation Uniformity and Efficiency in Florida”, the authors Melissa Baum, Michael Dukes and Grady Miller all with the University of Florida have done comparison studies of auditing techniques based upon the standards mentioned previously. In this case study, the audits involved hundreds of catch cans that covered the entire yard and placed in a grid pattern. Catch cans were placed five foot on center for spray heads and 10 foot on center for sprinkler zones with rotor heads. Catch cans were place about 30 inches from any structures, property boundaries or hardscapes to minimize the impact of “edge effects”. The basis for this method was derived from the standards previously mentioned. The results from doing an extensive audit on 19 homes in three different counties were likewise compared to the technique used by the mobile irrigation laboratories. In the comparison example, the largest zone of each of the nineteen homes using the grid procedure had a DU_{LQ} of 43.4% (range of 32-60%) while the Florida Mobile Irrigation Lab method of using 16-24 catch cans the DU_{LQ} was 55.1% (range of 36-70%). They also included the results of over 500 audits conducted by the Mobile Irrigation Laboratory of homes in seven different counties over the years.

Joe Kissinger, an independent auditor in southern California and consultant to several water agencies, provided the data for the California case study. These are audits he has done while doing studies to improve irrigation performance on existing sprinkler systems. The results were part of a report entitled “Landscape Water Conservation with Improved Irrigation Efficiency”.

A report entitled “Evaluating the Irrigation Efficiencies and Turf/Landscape Maintenance Practices on the Campus of Northern Arizona University” was the source of information and results for audits done on seven major turf areas at the Northern Arizona University in Flagstaff, Arizona.

A final report “Quantifying the Effectiveness of the Landscape Irrigation Auditing and Management Program” by Guy Fipps, Douglas F. Welsh and David W. Smith provided project results for six sites including a golf course, soccer field, football field, baseball field, a small commercial property and a residence. It was assumed that most of these properties are large and used rotor type heads and so the overall result is reported as rotors.

Results from Audits Performed:

The lower quarter distribution uniformity results from audits performed on residential sprinkler systems as well as large commercial type projects are given in the following table. Over 6800 audits are represented in this table with the average results shown.

Sprinkler System Performance

Residences		Fixed Spray				Rotors			
Location	# of Audits	Avg. DU_{LQ} %	Range %	Avg. PR (in/hr)	Range (in/hr)	Avg. DU_{LQ} %	Range %	Avg. PR (in/hr)	Range (in/hr)
Utah	4500	**52**		1.4	.70-3.70	**58**		.70	.10-2.30
Utah USU	164	**52**	18-80	1.57	.50-3.20	**49**	15-86	.76	.20-1.70
Colorado	973	**53**	20-89	1.34	.22-4.06	**54**	19-92	.62	.12-1.60
Oregon	398	**55***				**54***			
Florida MIL	576	**54**	11-89						
U of FL Case Study	19	**40**				**48**			
California Case study	19	**41**	16-54	1.61	.66-2.97				
Commercial		**Fixed Spray**				**Rotors**			
Location	# of Audits	Avg. DU_{LQ} %	Range %	Avg. PR (in/hr)	Range (in/hr)	Avg. DU_{LQ} %	Range %	Avg. PR (in/hr)	Range (in/hr)
Utah	166	**55**	7-82	1.49	.26-3.10	**55**	8-84	.74	.13-2.46
Colorado	20	**52**	6-77	1.36	.60-2.12	**50**	3-88	.60	.10-1.12
Arizona	7					**41**	20-56	.76	.57-.92
Texas	6					**58**	27-79		

* reflects the lower-third distribution uniformity information of 61 and 60 reduced by 6 points

Conclusion:

With over 6800 audits used to measure how well the typical sprinkler system performs it appears that the average DU_{LQ} is about 50% no matter what type of sprinkler head is being used. The results from the audits have in common that typically only one or two zones that appeared to be operating best (such as good coverage, no leaks or missing heads etc.) or were at least representative (by visual observation) of the sprinkler zones in the yard were actually audited for the residential programs. With that in mind, the overall sprinkler system distribution uniformity (DU_{LQ}) is probably less than what is reported in the above table. These findings are consistent with the findings from field assessments of irrigation system performance in California. Pitts et al. (1996) found less than desirable distribution uniformity values. The average DU for non-agricultural turfgrass sprinklers (residential lawns) was 49% with more than 40% of the tested systems having a DU of less than 40%.

By referring to the Quality Rating of Sprinkler Systems table most sprinkler systems fall into the “Fair” or “Poor” category. If water is a precious resource and there is such high demand upon water resources, this is not an acceptable situation.

Improving sprinkler system performance is an integral part of improving irrigation management so that overall irrigation efficiency can improve.

Another surprise is the fact that there seems to be very little difference in distribution uniformity between fixed spray heads and rotor heads. Frequently fixed spray heads are considered to have poor distribution uniformity and that is why they have a lower acceptable minimum distribution uniformity in the practice guidelines of the Irrigation Association's Turf and Landscape Best Management Practices. It can be seen from the audit results that most fixed spray zones come close to meeting the current BMP while rotor zones come up very short. As can be seen in the range of DU_{LQ}, either type of head can perform in the "Very Good" or "Excellent" category. Type or brand of equipment has the least impact on performance quality compared to proper design (including spacing, pressure and hydraulics), installation and maintenance.

Lastly what should be the realistic expectation of distribution uniformity of a sprinkler system? Should the IA BMPs state the minimum expectation or should the bar be raised? The current usage of the BMPs suggests that the minimum distribution uniformity as stated is the standard to be achieved. Some agencies such as Tucson Unified School District expect a 65% DU measured in the field on new projects. The City of Boulder, Colorado expects 70% distribution uniformity without regard to type of sprinkler head on commercial properties. As mentioned in the beginning the minimum DU_{LQ} considered acceptable in Australia is 75% and Georgia thinks that 80% DU_{LQ} is achievable for the average system. These higher expectations suggest that the irrigation industry including manufacturers, irrigation designers and contractors, needs to find ways to meet expectations and based upon the findings of these audits there is plenty of room for improvement. As water management is improved with the new technology of ET based controllers or soil moisture based controllers better performing sprinkler systems will be mandatory to properly manage water resources and achieve acceptable landscape quality and appearance

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